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# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## TECHNICAL NOTE 3951

# INVESTIGATION OF THE PLANING LIFT OF A FLAT PLATE AT SPEEDS UP TO 170 FEET PER SECOND

By Kenneth W. Christopher

Langley Aeronautical Laboratory
Langley Field, Va.



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# INVESTIGATION OF THE PLANING LIFT OF A FLAT PLATE AT SPEEDS UP TO 170 FEET PER SECOND

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## SUMMARY

An experimental investigation has been made in the Langley high-speed hydrodynamics facility to determine whether the planing lift coefficient of a flat-bottom planing surface remains constant with increasing speed at the high towing speeds obtainable from this facility. Measurements were made of lift and wetted area at speeds ranging from 80 to 170 fps over a range of trims from 4° to 30° and at wetted-length—beam ratios of approximately 2 and 5.

No effect of speed on the planing lift coefficient was noted for the range of speeds tested and the data agreed well with those recently obtained in lower speed towing tanks. These results confirm the generally accepted assumption that positive-pressure planing lift coefficients do not vary with speed even at speeds extending to full-scale take-off speeds.

## INTRODUCTION

Experimental planing investigations made in towing tanks have in the past been limited to speeds of 80 fps and below. The take-off speeds of water-based aircraft have been increasing, and speeds of the order of 200 fps are of current interest. The new Langley high-speed hydrodynamics facility is capable of providing data in this speed range.

It has been generally assumed that pure planing lift coefficients are practically unaffected by changes in speed if the planing surface has a shape that produces no substantial areas of negative pressure. This assumption has been confirmed by various investigations of flat and dead-rise planing surfaces up to the limiting speeds of existing towing tanks (ref. 1). It was the purpose of the present work to investigate the validity of such an assumption at speeds up to those approaching current full-scale take-off speeds. In this investigation, data were obtained on a flat plate in a speed range of 80 to 170 fps and for a trim-angle range of 4° to 30°.

This paper briefly describes the high-speed hydrodynamics facility and the testing techniques employed and presents the planing lift coefficients obtained from the present investigation. The planing lift coefficients are compared with theory and with values obtained at 80 fps and below in lower speed towing tanks.

## SYMBOLS

| | |
|---|---|
| $C_{L,S}$ | lift coefficient based on wetted area, $\frac{\text{Lift}}{\frac{1}{2}\rho V^2 S}$ |
| $C_{L,b}$ | lift coefficient based on beam, $\frac{\text{Lift}}{\frac{1}{2}\rho V^2 b^2}$ |
| $C_V$ | speed coefficient, $\frac{V}{\sqrt{gb}}$ |
| S | wetted area, sq ft |
| $\tau$ | trim, deg |
| V | speed, fps |
| b | beam, ft |
| $l_m$ | mean wetted length, ft |
| g | acceleration due to gravity, ft/sec$^2$ |
| $\rho$ | mass density of water, slugs/cu ft |

## DESCRIPTION OF MODELS

Two rectangular flat plates were used in the investigation, one having a beam of 4 inches and the other a beam of 8 inches. Both models were 9 beams long. A photograph of the models is shown in figure 1 and details are shown in figure 2. The smaller model was used for most of the investigation. The larger model was used for the tests involving low trim and low wetted-length—beam ratio in order to increase the forces to values more suitable for the balance in use.

The models were constructed of stainless steel. The planing bottoms of the models were machined to a tolerance of 0.002 inch with a roughness of less than 20 microinches, root mean square, and the chines and trailing edges were machined square and sharp. The lines and numbers shown in figure 1 were inked on the bottom of the models for photographic indentification of wetted length.

## APPARATUS AND PROCEDURE

### Facility

The Langley high-speed hydrodynamics facility consists of an open tank of water 2,200 feet long located beside the existing landing-loads track, as shown in figure 3. This arrangement makes possible the use of the rails, propulsion equipment, and arresting-gear system provided for landing-loads investigations.

Hydrodynamic tests are carried out from a boom on the carriage that extends over the tank to provide a support for the towing staff and model. At present, tests are carried out by using the landing-loads carriage with a temporary boom installed as shown in figure 4. This photograph also provides a close view of the tank itself, which is 8 feet wide and is filled with fresh water to a depth of 5 feet. Integral sloping beaches are provided along the entire length for the suppression of waves. In addition, plastic-screen wind deflectors are installed along the side of the tank to minimize the effect of wind on the water surface.

The carriage is accelerated by a water jet that is operated by compressed air and impinges on a turning bucket on the rear end of the carriage. It then coasts freely during a 1,200-foot test run and is brought to a stop by a cable arresting system that engages a receiver on the front end of the carriage. For the present investigation the deceleration while coasting was approximately 0.1g. The maximum speed available with the present carriage is approximately 200 fps. The maximum available for the present tests was about 170 fps because of temporary limitations of the arresting system.

Underwater photographs may be taken at five locations along the length of the tank. Three of the stations (numbered 1, 3, and 5) consist of tunnels with glass windows in the bottom of the tank for taking photographs. One of these (station 3) also includes a window in the side of the tank for taking photographs from the side. Cross sections of the tank at station 3 are shown in figure 5. Stations 2 and 4 consist of pits in the bottom of the tank into which watertight boxes containing cameras and lighting equipment can be placed. The five photographic stations are indicated in figure 3 by the sunshades over each station.

## Balance and Setup

Lift, drag, and pitching moment were measured in the present investigation by an electrical strain-gage balance attached to a hydraulically operated towing staff on the end of the boom (fig. 6). Raising and lowering the staff provided changes in draft and nominal wetted length. To eliminate air drag on the model, the model was run behind a windscreen which was adjusted to be approximately 1 inch above the water. The round bar shown clamped to the windscreen support held a target that interrupted the photocell beams and thereby triggered the underwater cameras.

The outputs of the strain-gage balance were fed to strip-chart recorders of the balancing potentiometer type located on the carriage. The measured drag and pitching moment were used to correct the lift data for balance interactions. Only the lift data, however, are presented.

Changes in trim of the model due to structural deflections caused by pitching moments were obtained during calibration of the balance. These changes, which did not exceed $0.3^{\circ}$ and in most cases were less than $0.1^{\circ}$, were compensated for by the presetting of a corrected trim angle before each run.

## Underwater Photographs

In the present investigation, photographic stations 1 and 3 were used. Underwater photographs for the determination of wetted lengths and areas were taken at these stations with 70-millimeter cameras and high-speed light sources. A sample photograph is shown in figure 7.

A magnetic device was employed to produce pips on the balance records when the photographs were taken and thus to provide synchronization of the force and wetted-area data. The associated speed was determined by electronically measuring the time for the model to travel a distance of 10 feet across the photographic station.

## Precision and Scope

The accuracy of the quantities measured is estimated to be within the following limits:

| | |
|---|---|
| Lift, lb . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±12.0 |
| Wetted length, ft . . . . . . . . . . . . . . . . . . . . . . . . | ±0.02 |
| Trim, deg . . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±0.15 |
| Speed, fps . . . . . . . . . . . . . . . . . . . . . . . . . . . | ±0.15 |

The measured density of the tank water during the tests was 1.942 slugs per cubic foot. The kinematic viscosity varied because of temperature changes from $11.93 \times 10^{-6}$ to $13.55 \times 10^{-6}$ ft$^2$/sec.

A range of speeds was investigated from 80 to 170 fps over a range of trims from $4^{\circ}$ to $30^{\circ}$ and nominal wetted-length—beam ratios of 2 and 5. The actual measured wetted-length—beam ratios fell somewhat above and below the nominal values because of small differences in water level with respect to the model during the run.

## RESULTS AND DISCUSSION

The essential data are given in table I. Figure 8 shows a comparison of these data with the theory of reference 1 for flat plates with sharp chines and with recent experimental data obtained in lower speed towing ranks (refs. 1 and 2).

In general the present results agree with the previous data. The differences shown are of about the same magnitude as the scatter of test points and are not considered significant. Where differences do occur, the present data tend to be slightly higher, but the agreement is about as good as that normally found between different investigations of flat planing surfaces. (See ref. 1.) The theoretical curves shown have been found to be in reasonably good agreement with a large amount of planing data from various investigations and the agreement of the theoretical curves with the present data is also reasonably good.

Inspection of the data indicates that there is no significant effect of speed over the range covered. This agreement within the new data and the agreement between the new data and previous lower speed data provides confirmation of the generally accepted assumption that positive-pressure planing lift coefficients do not vary with speed over the range extending from normal tank-test speeds to full-scale take-off speeds.

A comparison of the lift coefficients obtained with the 4-inch-beam model and the 8-inch-beam model indicates no consistent scale effects between these model sizes.

## CONCLUSION

The generally accepted assumption that there is no effect of speed on the lift coefficient of positive-pressure lifting surfaces is valid at least up to 170 fps.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 13, 1956.

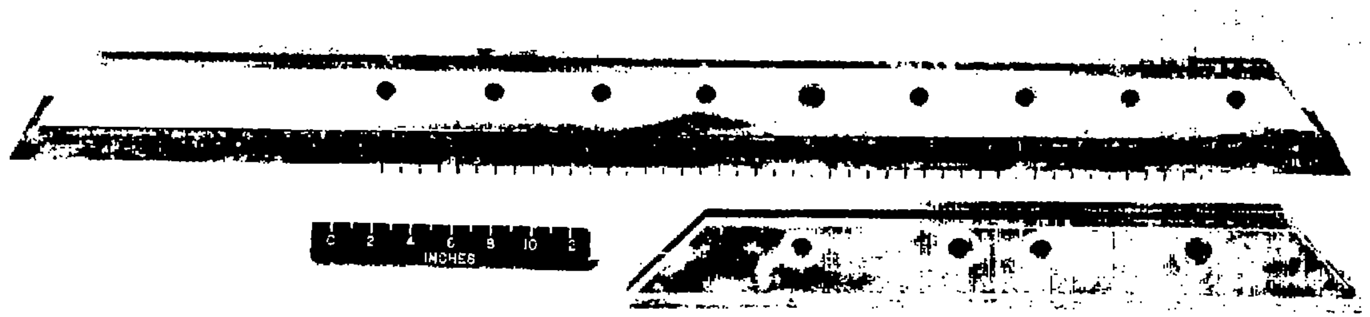
## REFERENCES

1. Shuford, Charles L., Jr.: A Theoretical and Experimental Study of Planing Surfaces Including Effects of Cross Section and Plan Form. NACA TN 3939, 1957.

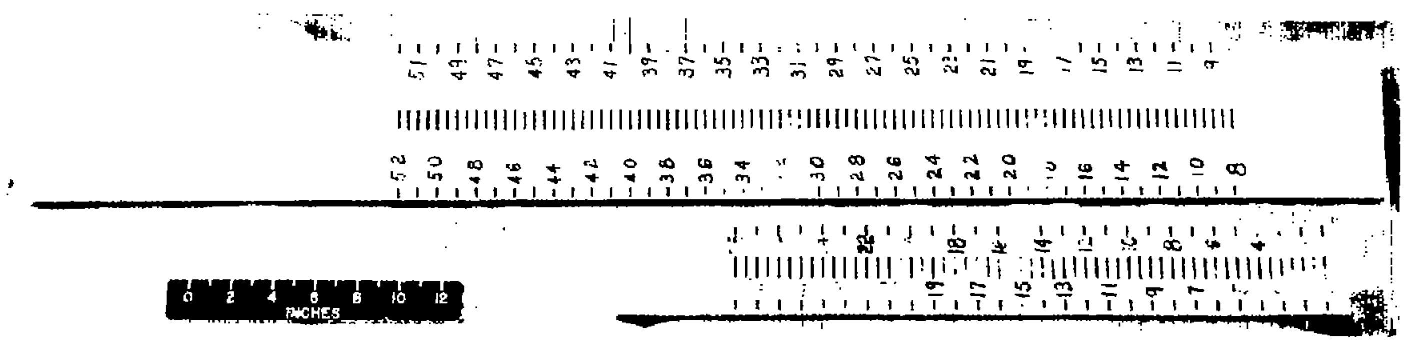
2. Weinstein, Irving, and Kapryan, Walter J.: The High-Speed Planing Characteristics of a Rectangular Flat Plate Over a Wide Range of Trim and Wetted Length. NACA TN 2981, 1953.

TABLE I.- LIFT DATA

| b, ft | $\tau$, deg | $\frac{l_m}{b}$ | V, fps | $C_V$ | $C_{L,S}$ | $C_{L,b}$ |
|---|---|---|---|---|---|---|
| 0.667 | 4 | 5.56 | 169.6 | 36.60 | 0.0232 | 0.1290 |
| .667 | 8 | 1.99 | 139.8 | 30.17 | .1032 | .2054 |
| .667 | 8 | 1.80 | 154.3 | 33.30 | .1081 | .1946 |
| .667 | 8 | 5.23 | 141.0 | 30.43 | .0636 | .3326 |
| .333 | 12 | 5.48 | 80.1 | 24.45 | .1048 | .5743 |
| .333 | 12 | 5.32 | 147.4 | 44.99 | .1080 | .5746 |
| .667 | 12 | 2.03 | 81.1 | 17.50 | .1611 | .3270 |
| .667 | 12 | 1.83 | 90.8 | 19.60 | .1734 | .3173 |
| .333 | 18 | 2.33 | 80.3 | 24.51 | .2394 | .5578 |
| .333 | 18 | 2.50 | 89.1 | 27.20 | .2311 | .5778 |
| .333 | 18 | 2.60 | 98.9 | 30.19 | .2420 | .6292 |
| .333 | 18 | 2.10 | 143.0 | 43.65 | .2552 | .5359 |
| .333 | 18 | 2.45 | 147.9 | 45.14 | .2409 | .5902 |
| .333 | 18 | 2.32 | 161.4 | 49.27 | .2510 | .5823 |
| .333 | 18 | 5.43 | 79.4 | 24.24 | .1821 | .9888 |
| .333 | 18 | 5.33 | 88.9 | 27.14 | .1858 | .9903 |
| .333 | 18 | 5.44 | 111.8 | 34.13 | .1832 | .9966 |
| .333 | 18 | 5.15 | 137.4 | 41.94 | .1858 | .9569 |
| .333 | 18 | 5.50 | 141.5 | 43.19 | .1802 | .9911 |
| .667 | 18 | 2.35 | 79.5 | 17.16 | .2470 | .5805 |
| .667 | 18 | 2.31 | 88.8 | 19.17 | .2463 | .5690 |
| .667 | 18 | 5.50 | 75.9 | 16.38 | .1839 | 1.0115 |
| .667 | 18 | 5.59 | 84.5 | 18.24 | .1845 | 1.0314 |
| .333 | 30 | 2.53 | 88.4 | 26.98 | .3828 | .9685 |
| .333 | 30 | 2.46 | 96.2 | 29.36 | .3950 | .9717 |
| .333 | 30 | 5.83 | 91.5 | 27.93 | .3163 | 1.8440 |
| .333 | 30 | 5.75 | 94.4 | 28.81 | .3229 | 1.8567 |
| .333 | 30 | 5.35 | 153.1 | 46.73 | .3212 | 1.7184 |




(a) Side views.




(b) Bottom views. L-95912

Figure 1.- Photographs of models.

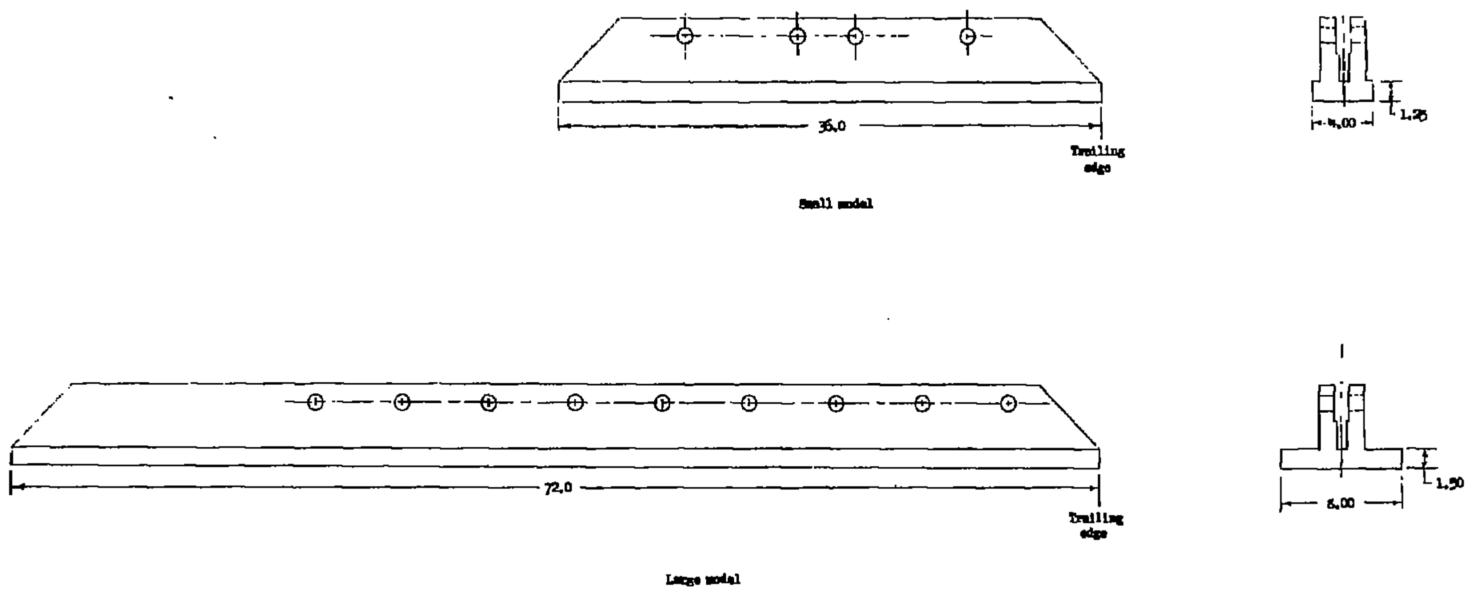



Figure 2.- Details of models. All dimensions are in inches.

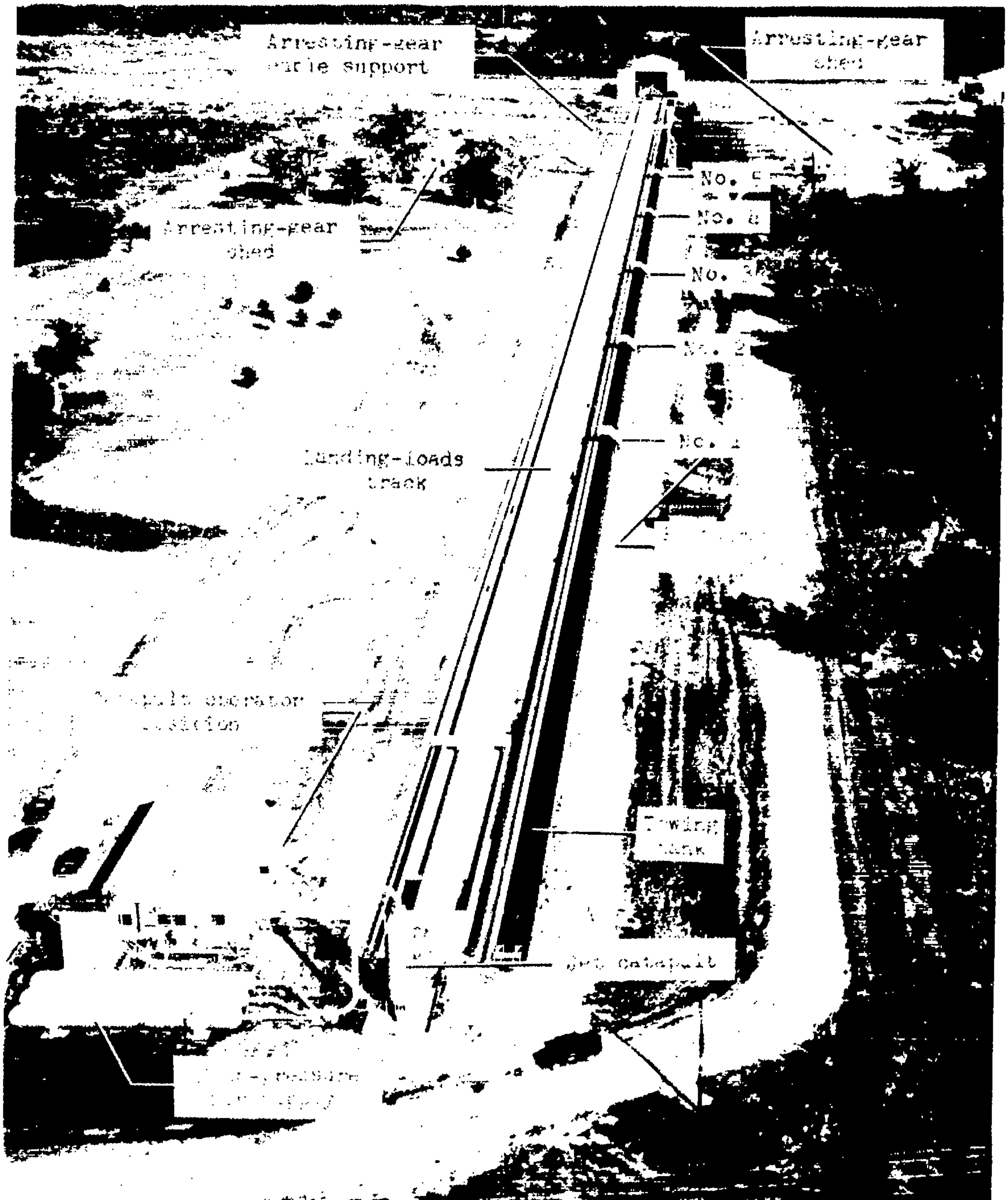



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Figure 3.- Aerial view of the Langley high-speed hydrodynamics facility.

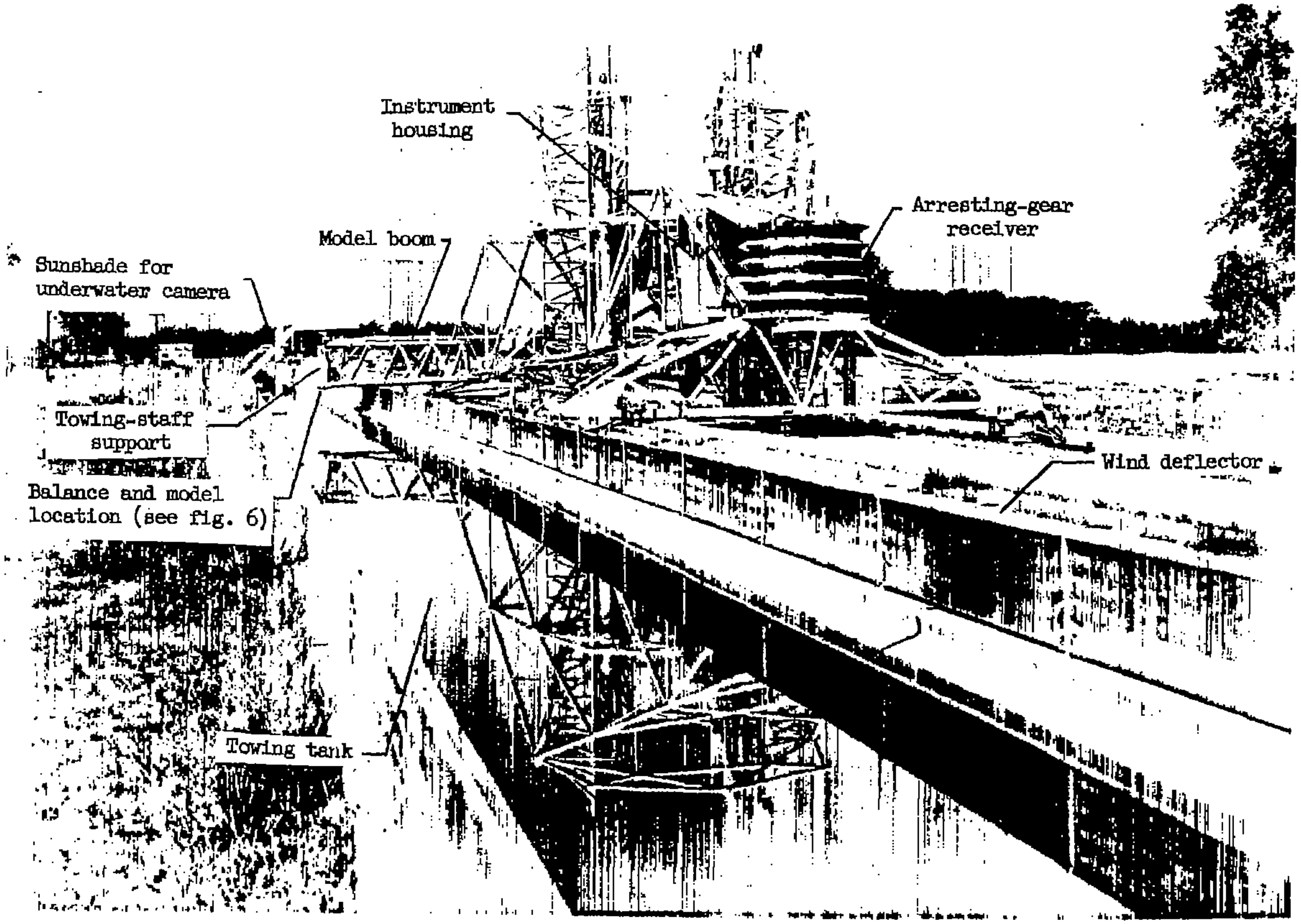


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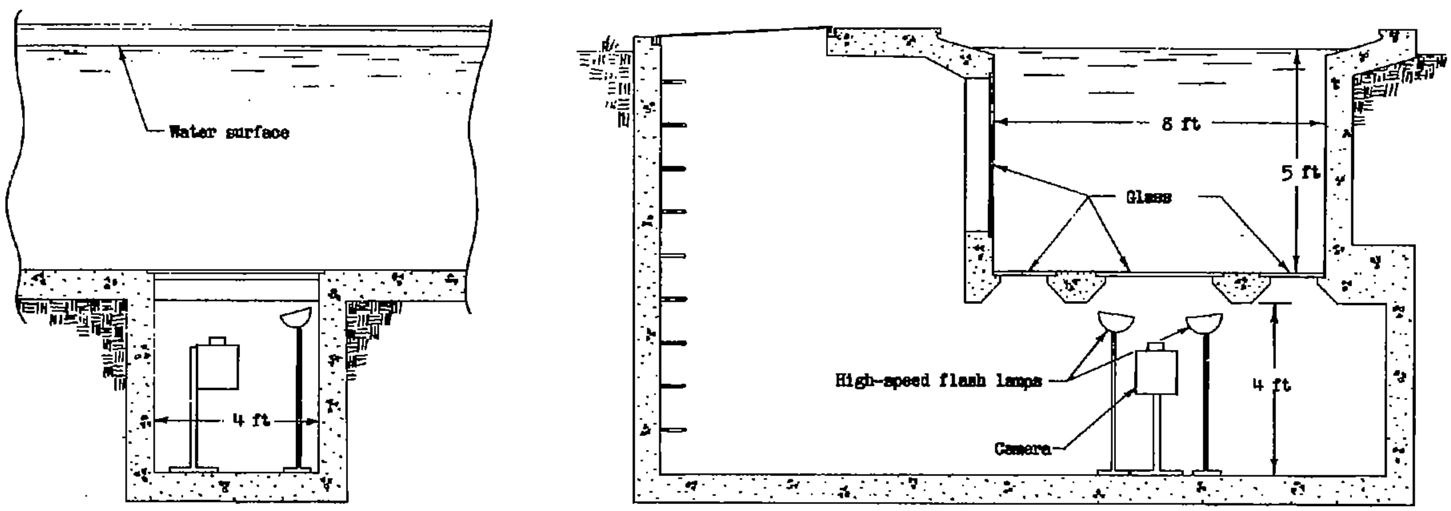
Figure 4.- Photograph of landing-loads carriage with temporary boom installed.




(a) Longitudinal cross section.

(b) Transverse cross section.

Figure 5.- Cross sections of the tank at photographic station 3.

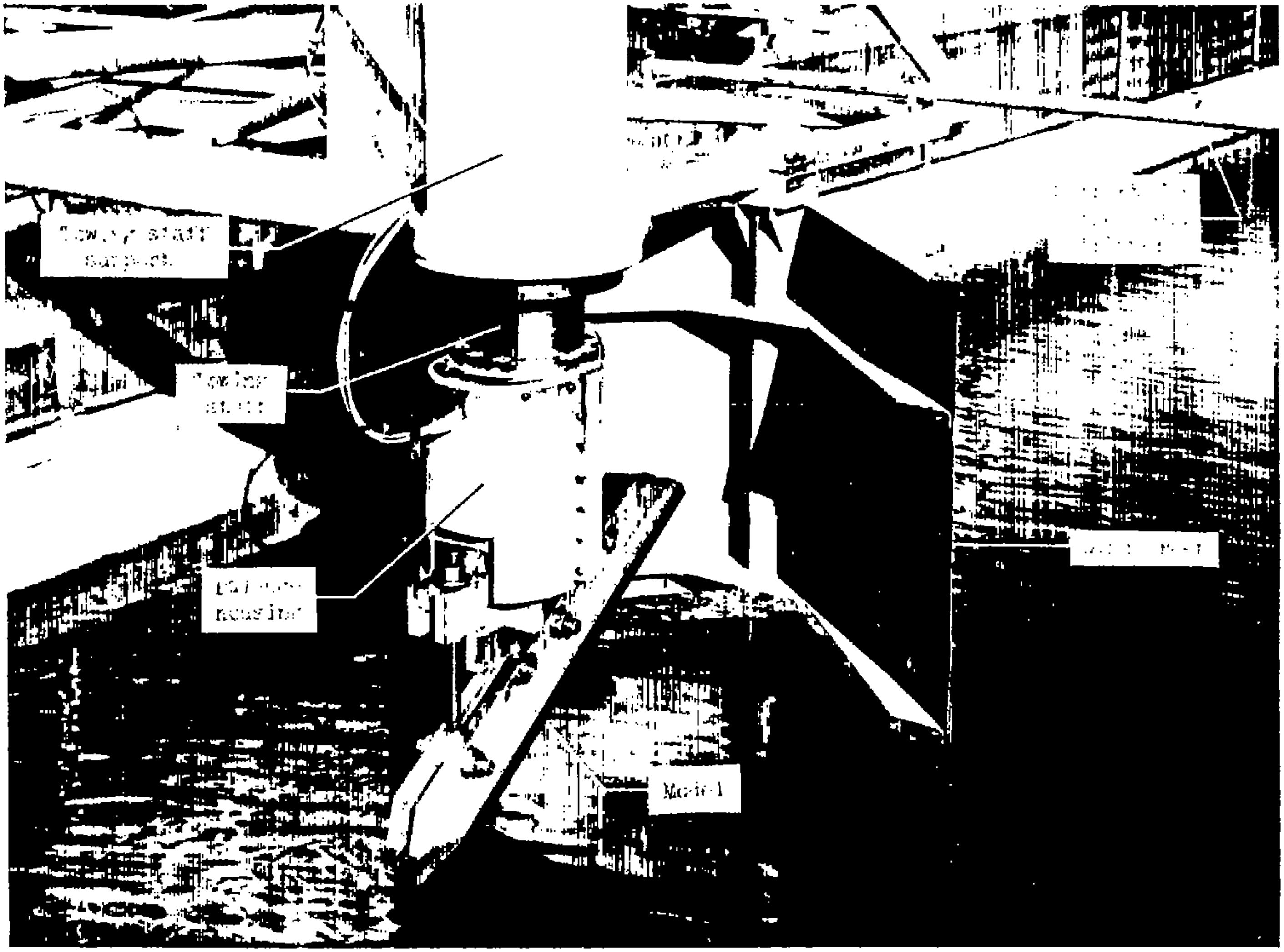


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Figure 6.- Photograph of test setup with 4-inch-beam model installed.


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Figure 7.- Typical underwater photograph. $\tau = 18^{\circ}$; $V = 98.9$ fps.

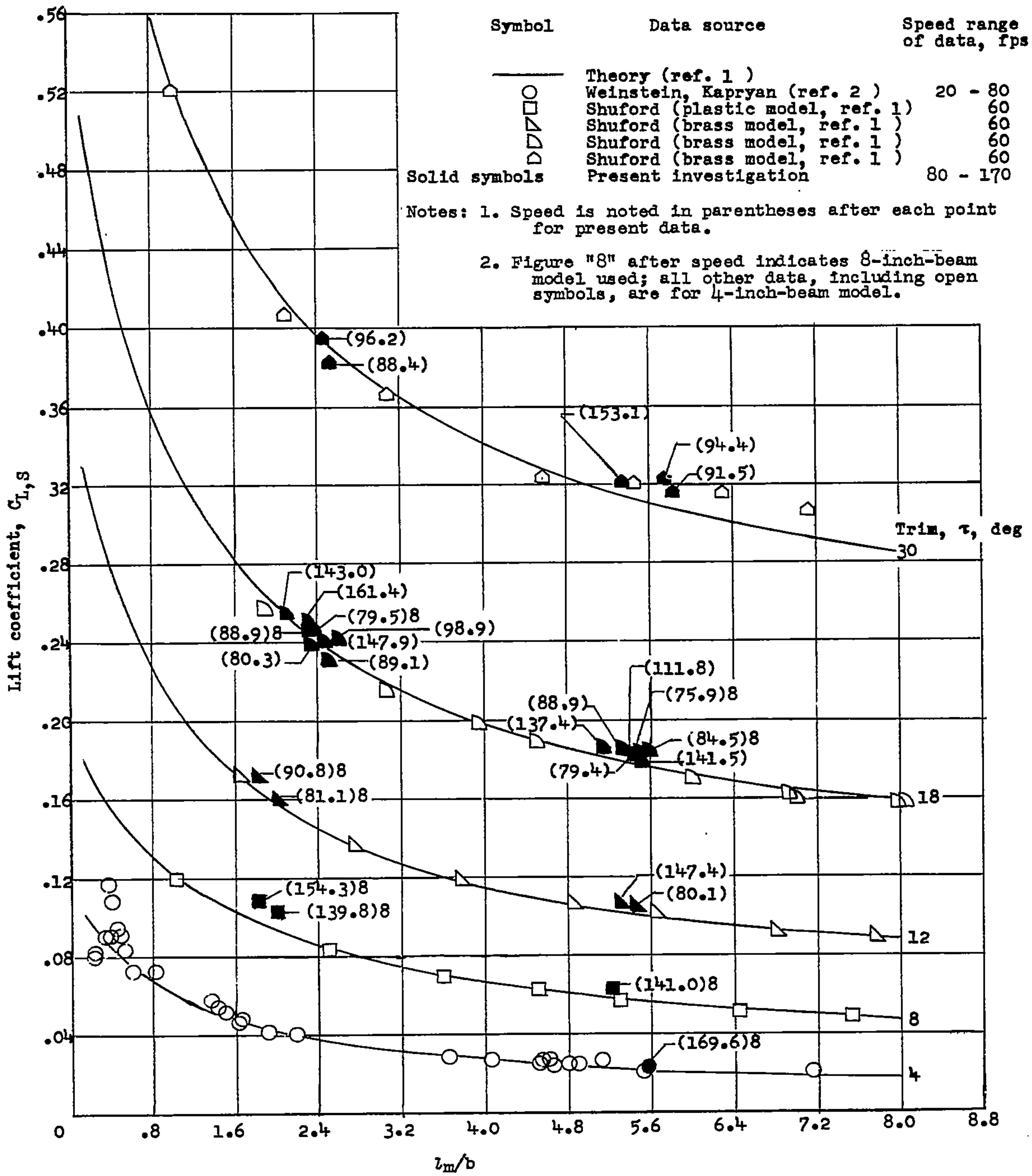


Figure 8.- Comparison of data from the high-speed hydrodynamics facility with theory and with data from lower speed towing tanks.